US011672099B2

(12) **United States Patent**
Gao

(10) **Patent No.: US 11,672,099 B2**
(45) **Date of Patent: Jun. 6, 2023**

(54) **SYSTEM LEVEL STRUCTURE FOR BLIND MATING CONNECTIONS**

(71) Applicant: **BAIDU USA LLC**, Sunnyvale, CA (US)

(72) Inventor: **Tianyi Gao**, San Jose, CA (US)

(73) Assignee: **BAIDU USA LLC**, Sunnyvale, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 79 days.

(21) Appl. No.: **17/209,917**

(22) Filed: **Mar. 23, 2021**

(65) **Prior Publication Data**

US 2022/0312638 A1 Sep. 29, 2022

(51) **Int. Cl.**
H05K 7/20 (2006.01)

(52) **U.S. Cl.**
CPC ***H05K 7/20272*** (2013.01); ***H05K 7/20781*** (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

8,894,431	B2	11/2014	Tiberghien et al.	
9,961,800	B2 *	5/2018	Jin	H05K 7/20509
10,188,016	B2 *	1/2019	Lunsman	H05K 7/20263
10,571,635	B1 *	2/2020	Leigh	H04Q 11/0005
10,863,652	B1 *	12/2020	Conroy	H05K 7/20763
11,064,628	B2 *	7/2021	Thibaut	H05K 7/1489
11,129,292	B1 *	9/2021	Shao	H05K 7/1485
11,252,844	B2 *	2/2022	Shao	H05K 7/20509
11,330,741	B2 *	5/2022	Shao	H05K 7/20272
11,399,448	B1 *	7/2022	Gao	H05K 7/20781
2016/0066480	A1 *	3/2016	Eckberg	F16L 37/34 361/679.53
2017/0257980	A1 *	9/2017	Fukunaga	F16L 37/40
2018/0242478	A1 *	8/2018	Cui	H01R 3/08

FOREIGN PATENT DOCUMENTS

CN	112020264 A	12/2020

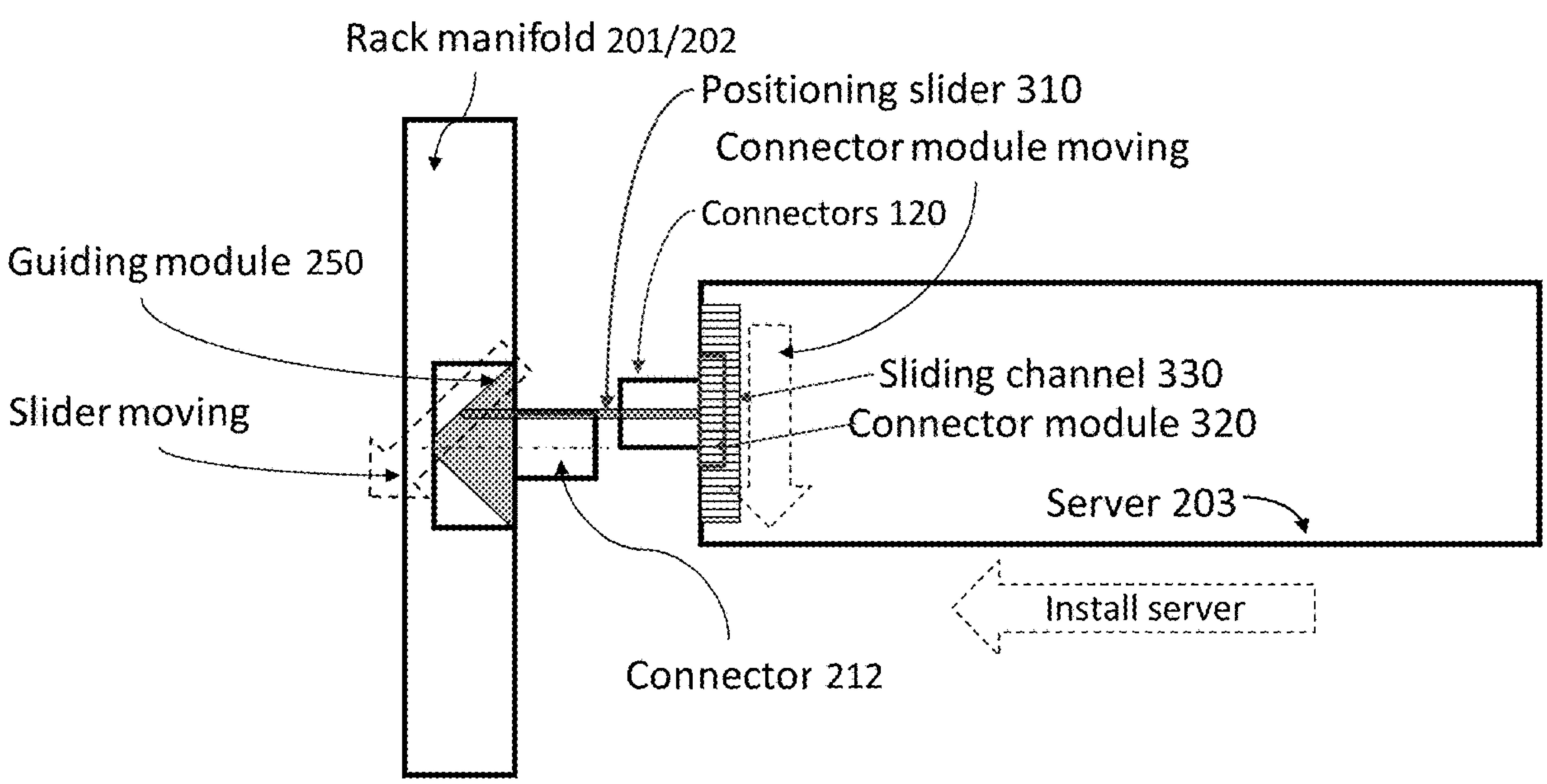
* cited by examiner

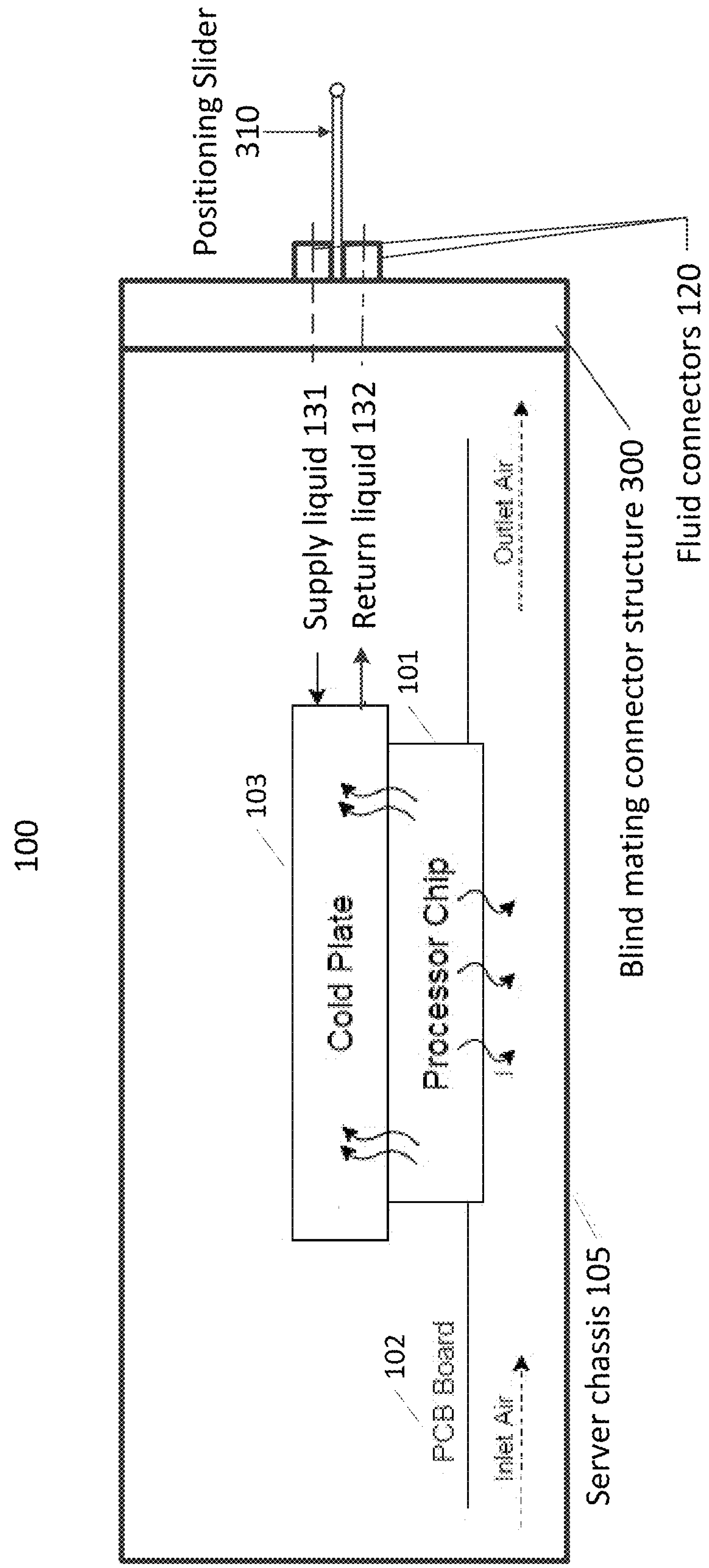
Primary Examiner — Courtney L Smith
(74) *Attorney, Agent, or Firm* — Womble Bond Dickinson (US) LLP

(57) **ABSTRACT**

A blind mating connection structure for servers is disclosed. On the server side, a connector module has fluid connectors to be blind mated to fluid connectors on rack manifolds in a server rack. The connector module is coupled to a sliding channel on the server. The connector module slides horizontally and vertically in response to movement of a positioning slider on the connector module. On the rack manifold side, a guiding module has an opening that receives the positioning slider when the server is installed in the server rack. The guiding module tapers down to a centering point midway between each rack manifold. As the server is slid into the server rack, the positioning slider follows the guiding module to the center point, moving the connector module into alignment with the fluid connectors on the rack manifold for blind mating.

20 Claims, 11 Drawing Sheets





100
Positioning Slider 310
Fluid connectors 120
Supply liquid 131
Return liquid 132
Blind mating connector structure 300
Outlet Air
101
103
Cold Plate
Processor Chip
102
PCB Board
Inlet Air
Server chassis 105

FIG. 1

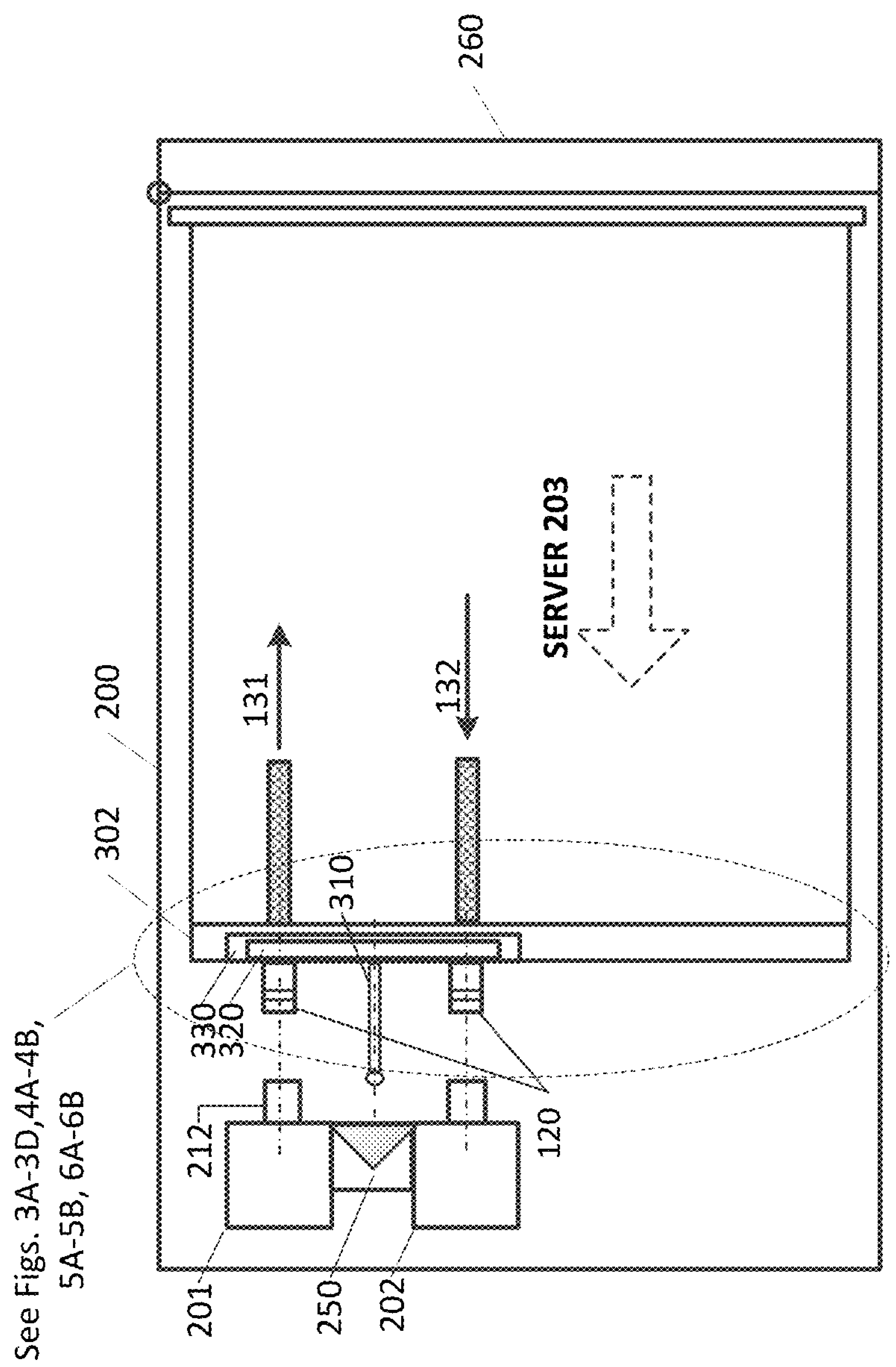

260
200
131
132
SERVER 203
302
310
330
320
120
212
See Figs. 3A-3D,4A-4B,
5A-5B, 6A-6B
201
250
202

FIG. 2

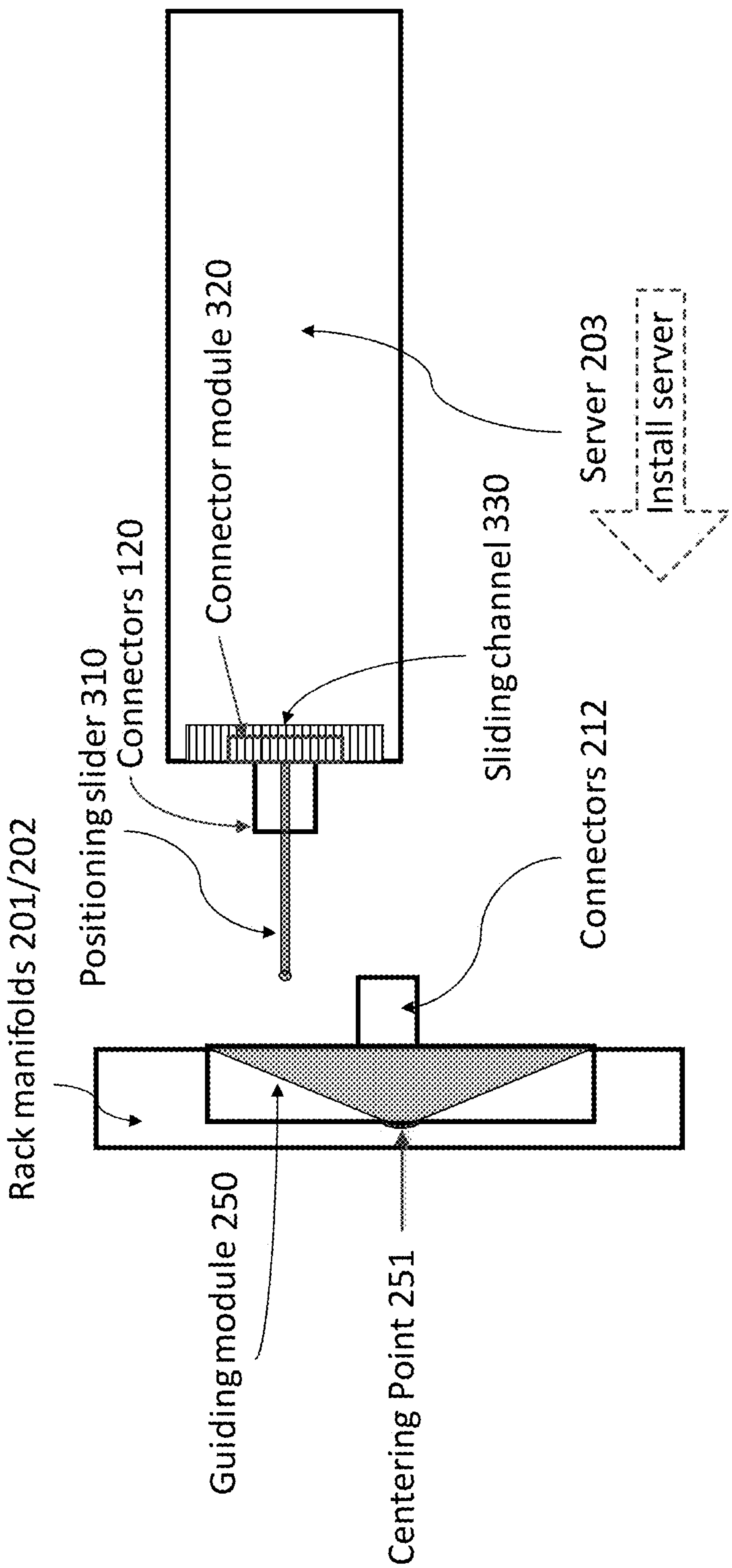

Connector module 320
Server 203
Install server
Connectors 120
Sliding channel 330
Positioning slider 310
Connectors 212
Rack manifolds 201/202
Guiding module 250
Centering Point 251

FIG. 3A

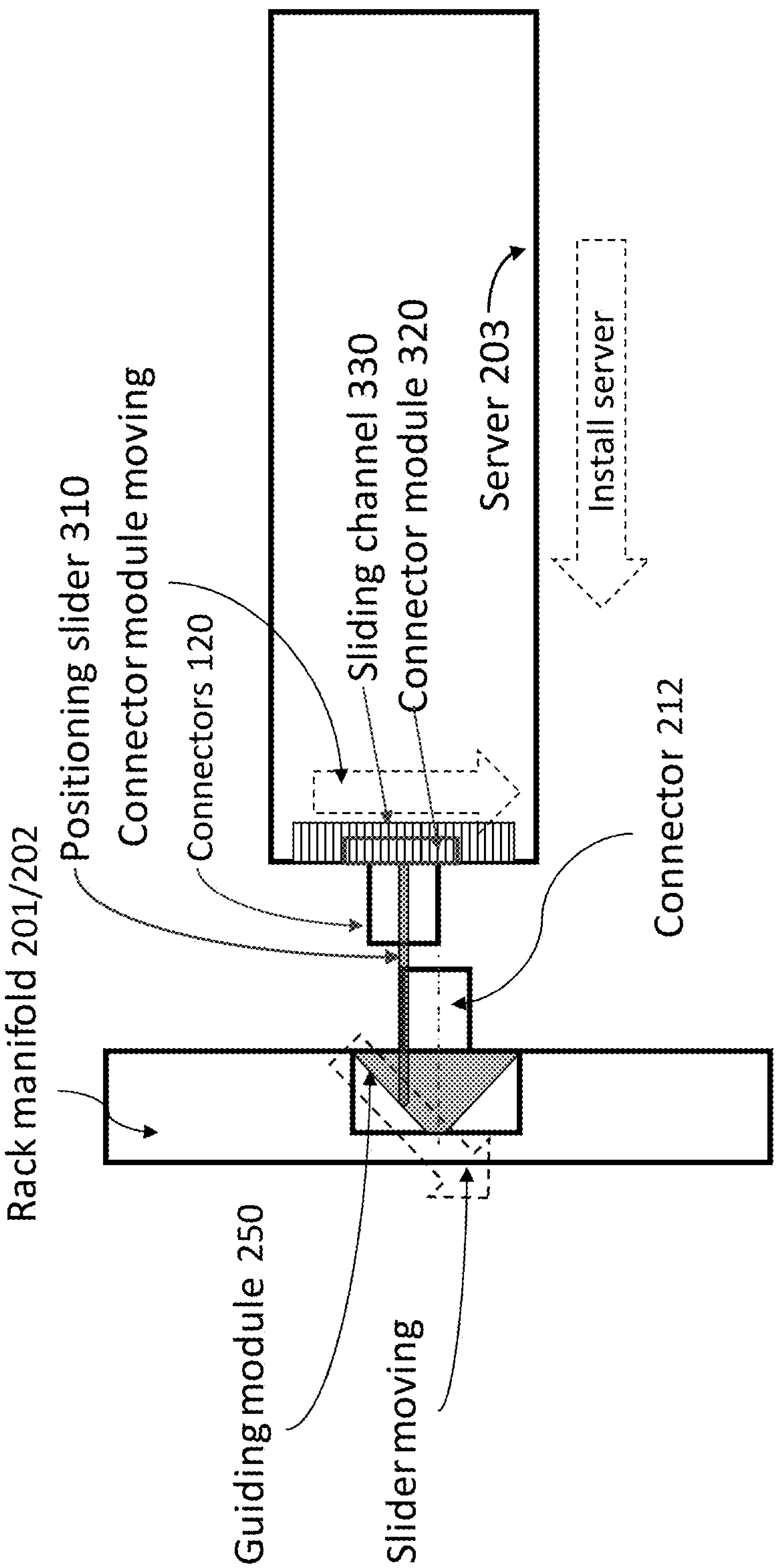

Rack manifold 201/202
Positioning slider 310
Connector module moving
Connectors 120
Sliding channel 330
Connector module 320
Server 203
Install server
Connector 212
Guiding module 250
Slider moving

FIG. 3B

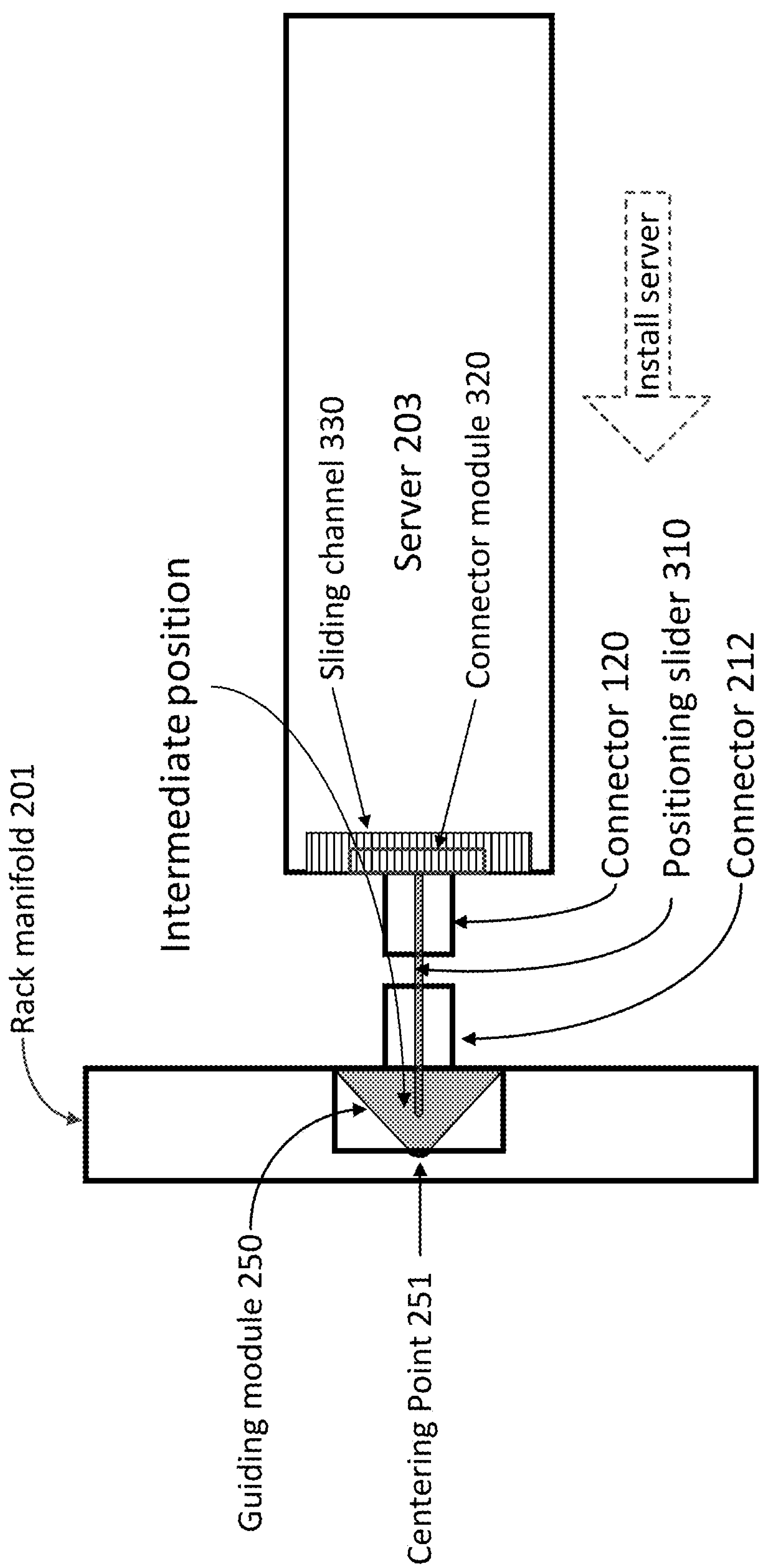
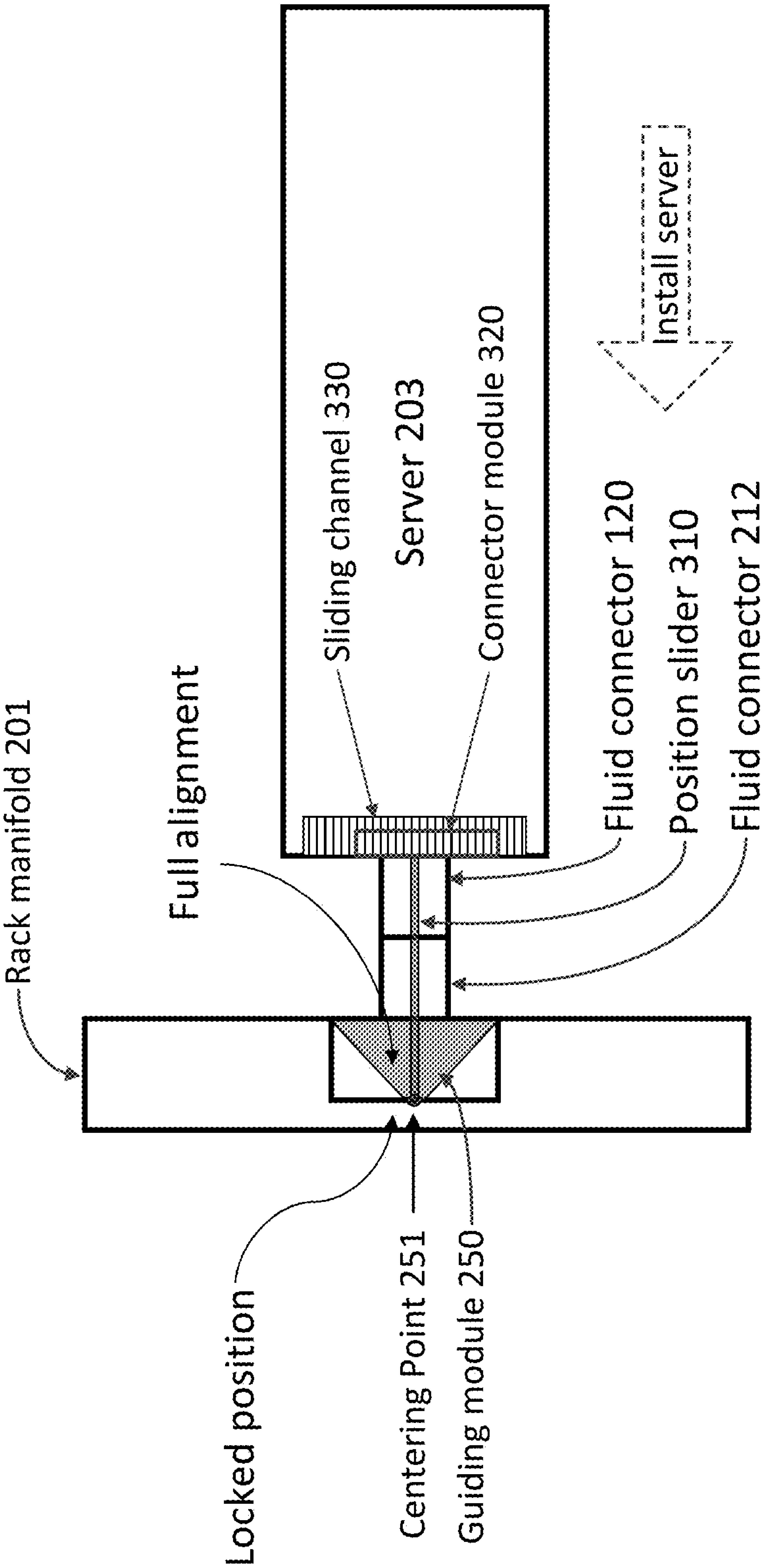

Rack manifold 201
Intermediate position
Sliding channel 330
Server 203
Connector module 320
Install server
Connector 120
Positioning slider 310
Connector 212
Guiding module 250
Centering Point 251

FIG. 3C



Rack manifold 201
Full alignment
Sliding channel 330
Server 203
Connector module 320
Install server
Fluid connector 120
Position slider 310
Fluid connector 212
Locked position
Centering Point 251
Guiding module 250

Fig. 3D

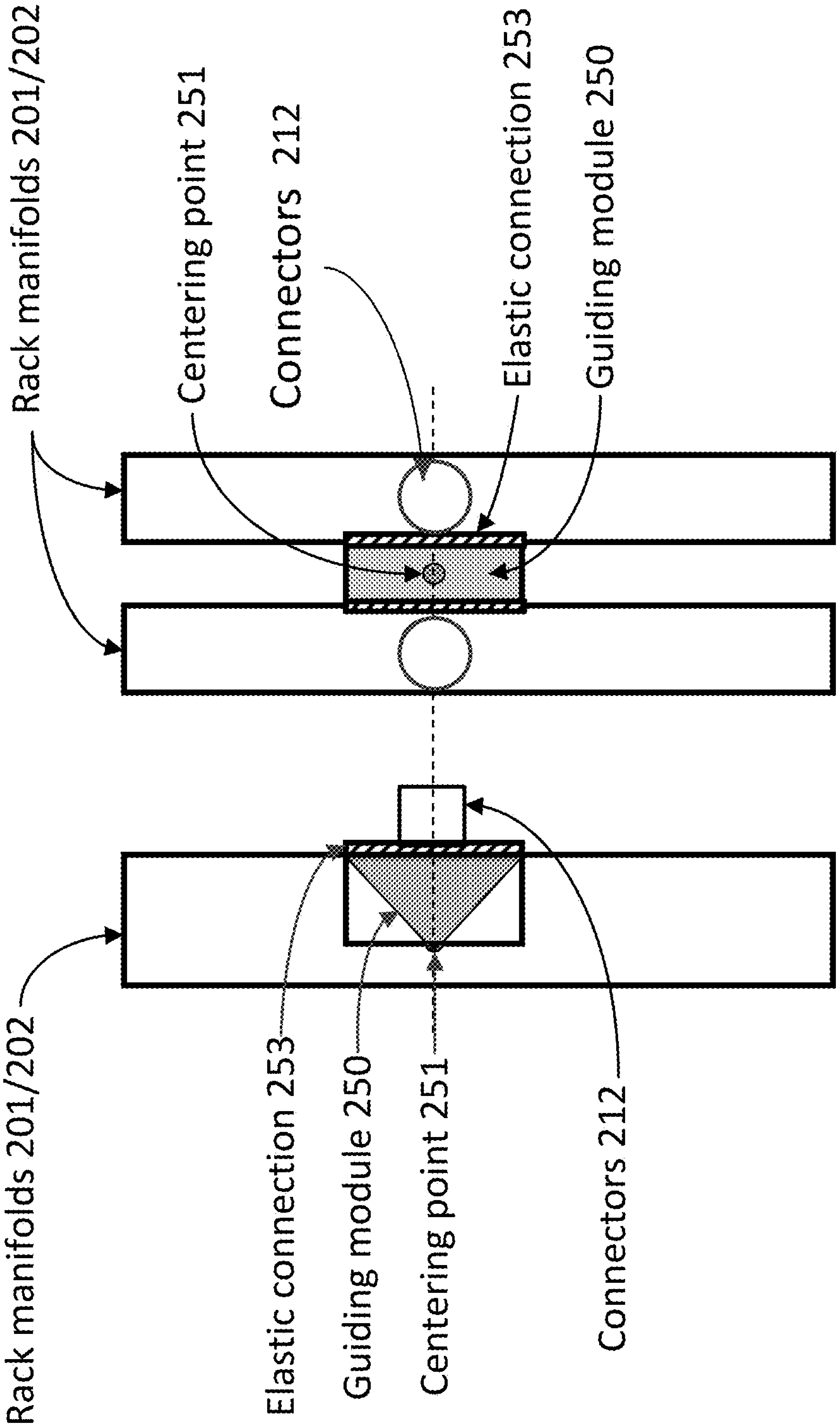


FIG. 4B
End view

FIG. 4A
Side view

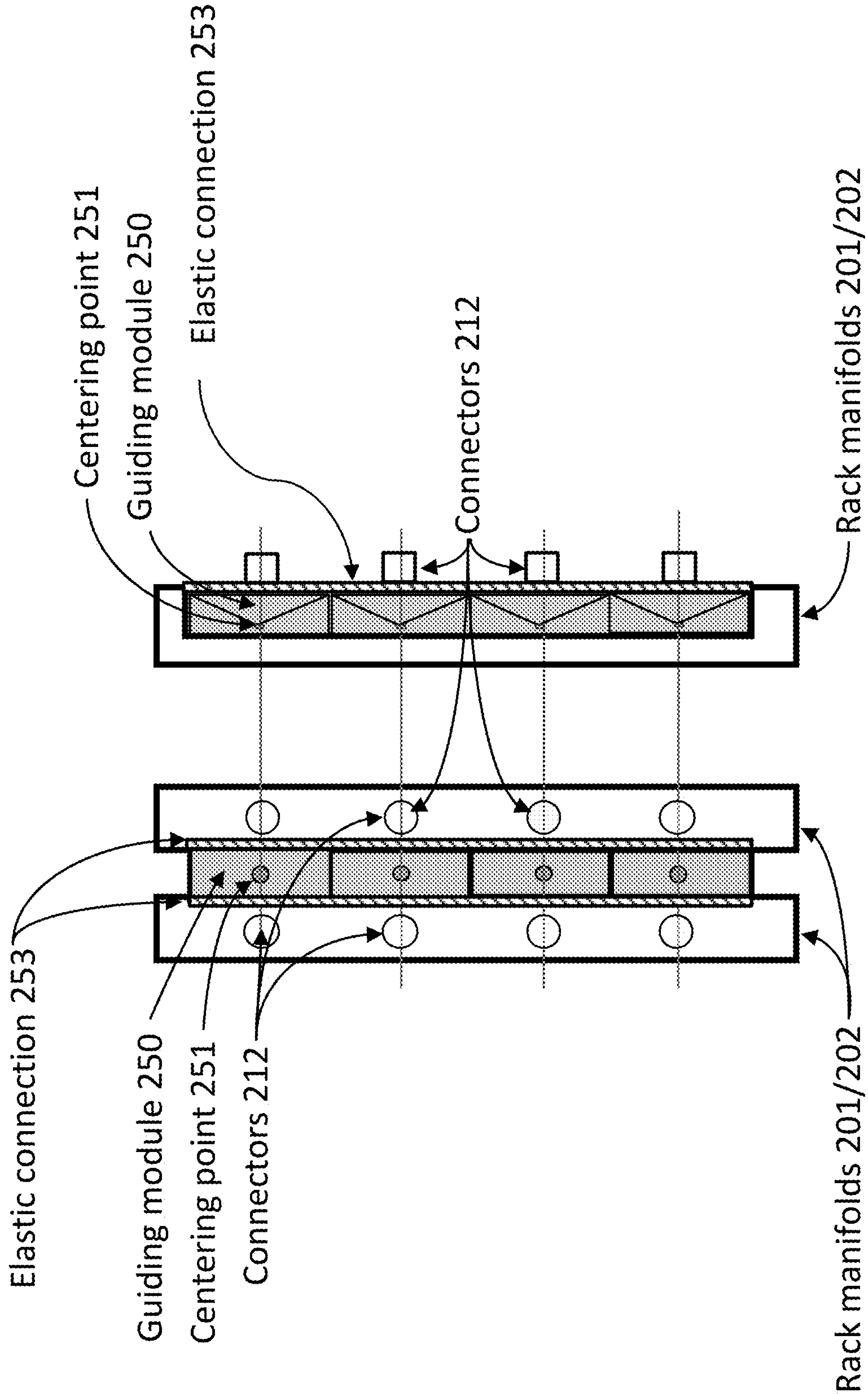
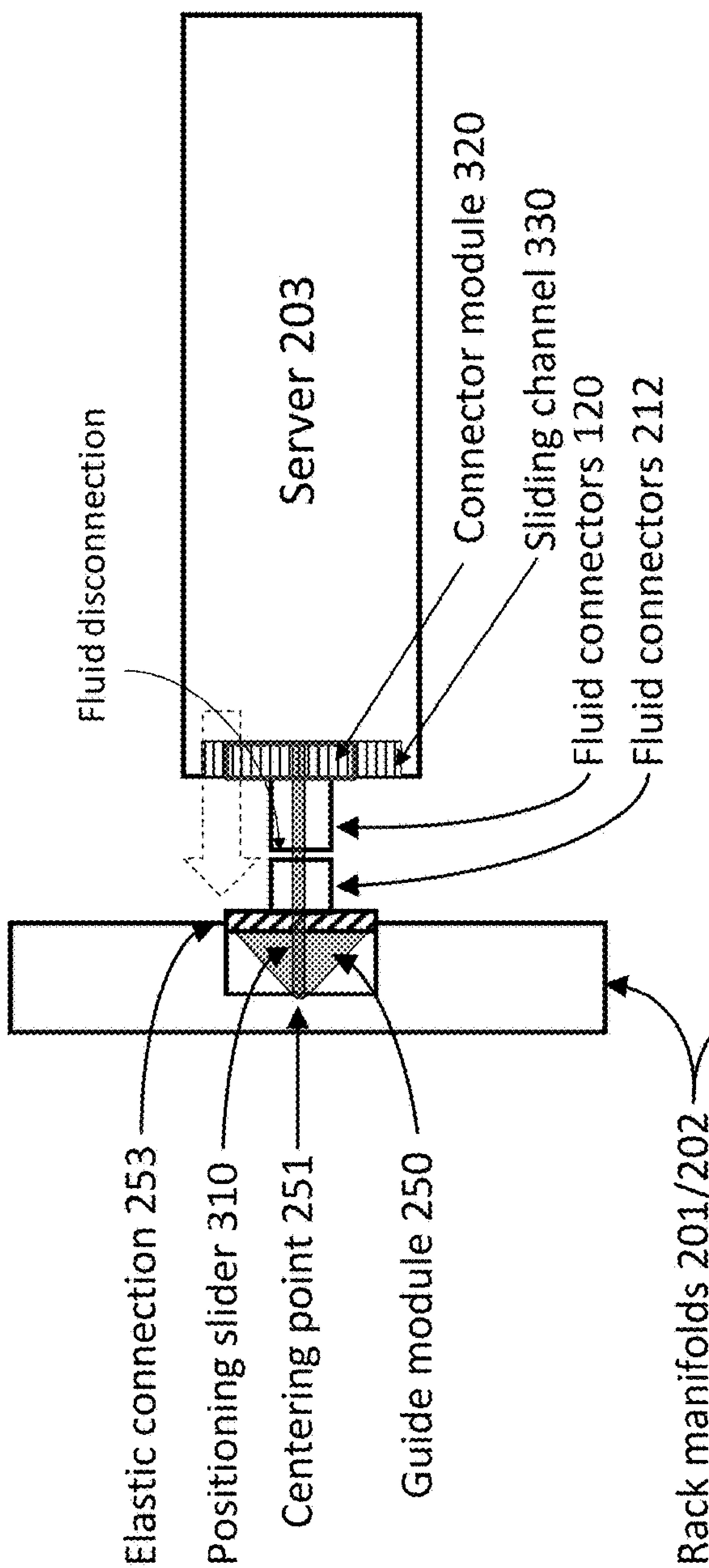


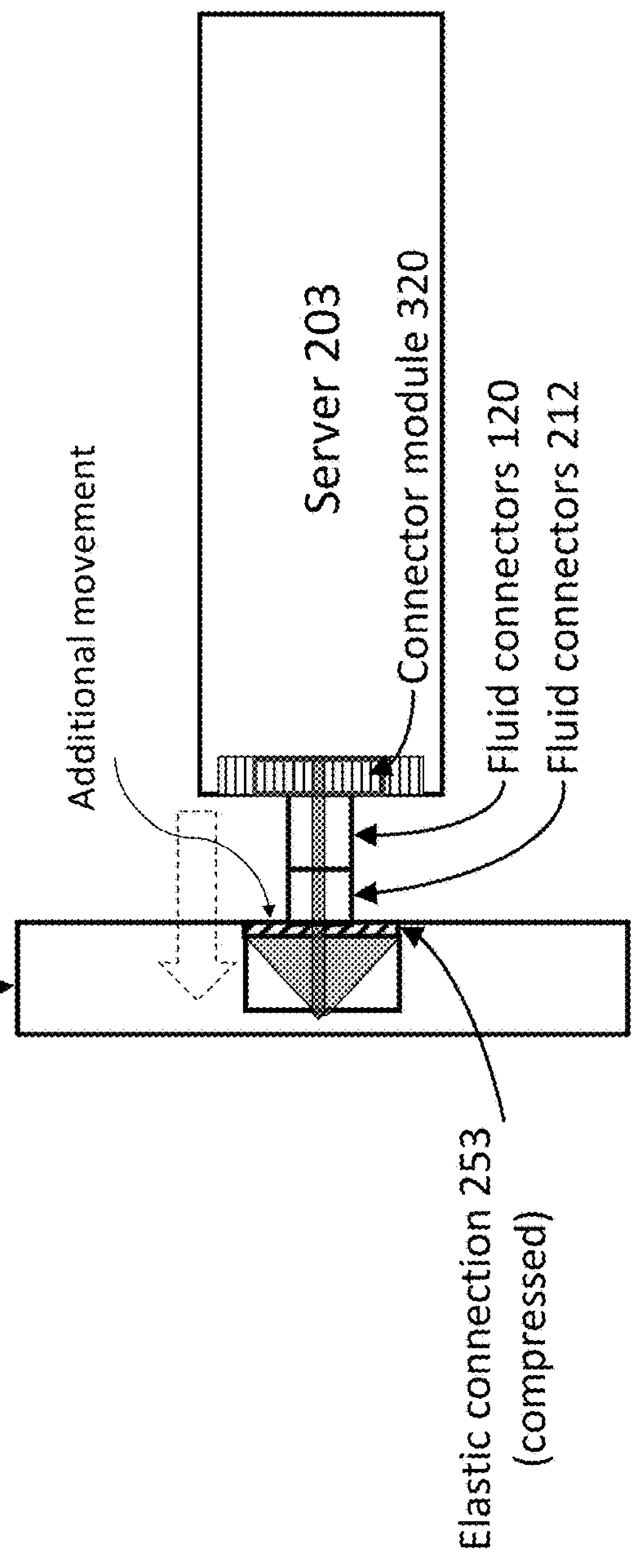
FIG. 5A
End view

FIG. 5B
Side view



Server 203
Connector module 320
Sliding channel 330
Fluid connectors 120
Fluid connectors 212
Fluid disconnection
Elastic connection 253
Positioning slider 310
Centering point 251
Guide module 250
Rack manifolds 201/202

FIG. 6A



Server 203
Connector module 320
Fluid connectors 120
Fluid connectors 212
Additional movement
Elastic connection 253
(compressed)

FIG. 6B

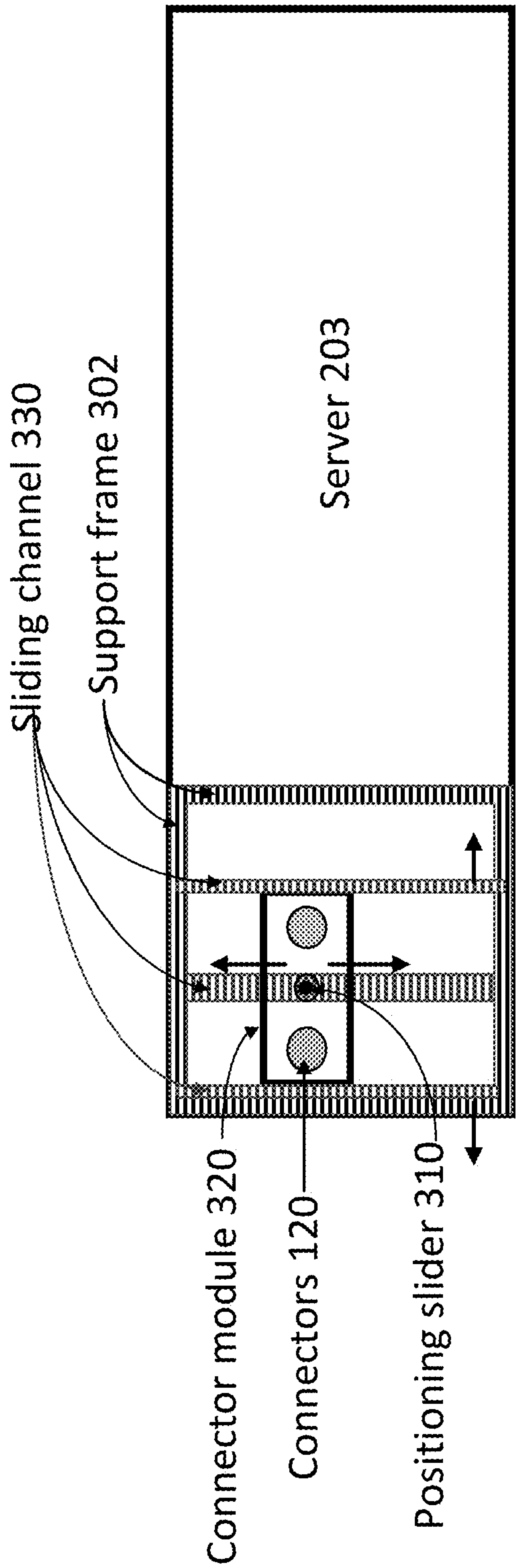

Server 203
Sliding channel 330
Support frame 302
Connector module 320
Connectors 120
Positioning slider 310

FIG. 7

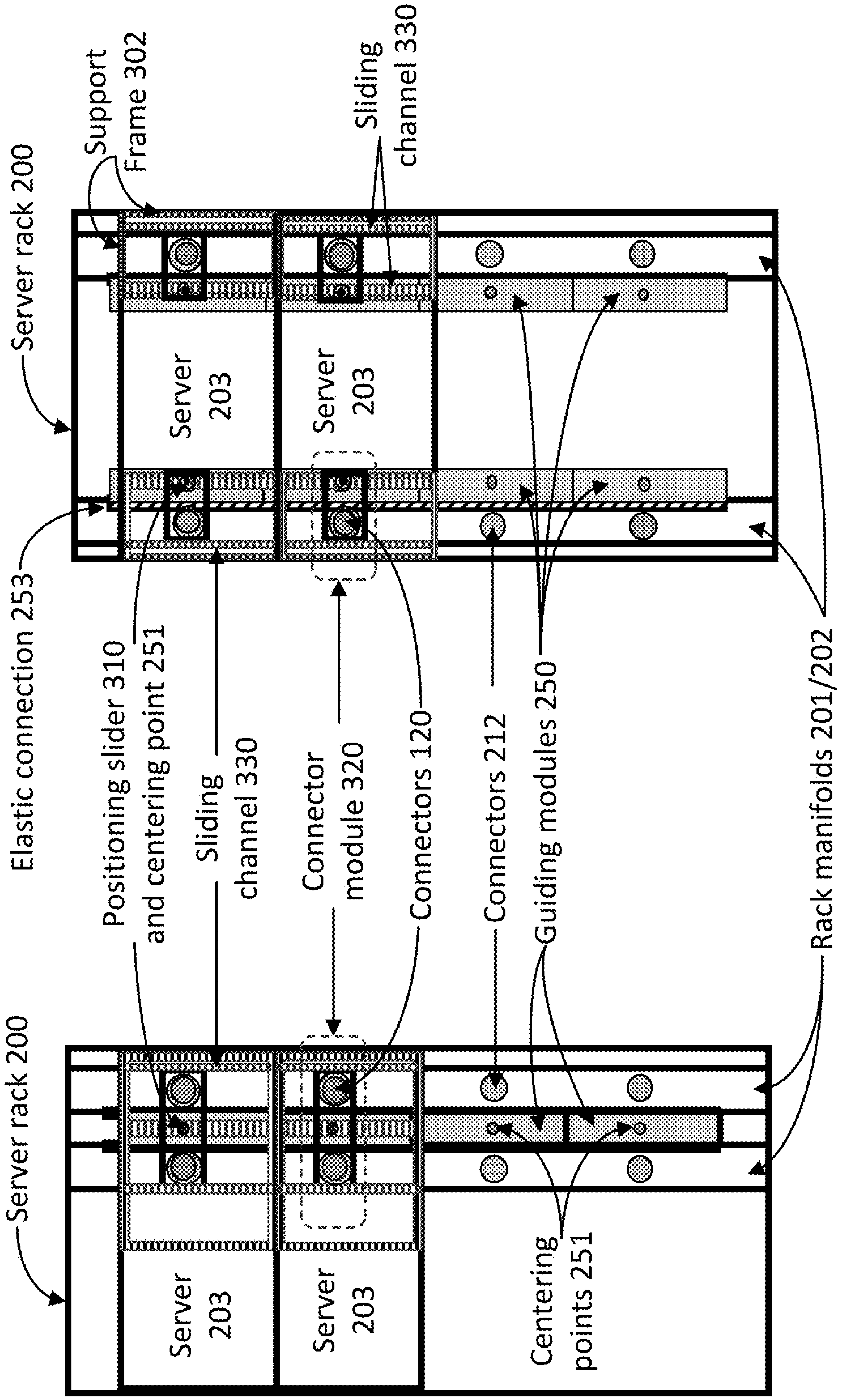

Server rack 200
Support Frame 302
Sliding channel 330
Server 203
Server 203
Elastic connection 253
Positioning slider 310 and centering point 251
Sliding channel 330
Connector module 320
Connectors 120
Connectors 212
Guiding modules 250
Rack manifolds 201/202
Server rack 200
Server 203
Server 203
Centering points 251

FIG. 8B

FIG. 8A

SYSTEM LEVEL STRUCTURE FOR BLIND MATING CONNECTIONS

FIELD OF THE INVENTION

Embodiments of the present invention relate generally to server and electronic cooling. More particularly, embodiments of the invention relate to server racks, including installation and removal of server equipment that connects to a liquid cooling module.

BACKGROUND

Cooling is a prominent factor in a computer system and data center design. The number of high performance electronics components such as high performance processors packaged inside servers has steadily increased, thereby increasing the amount of heat generated and dissipated during the ordinary operations of the servers. The reliability of servers used within a data center decreases if the environment in which they operate is permitted to increase in temperature over time. Maintaining a proper thermal environment is critical for normal operations of these servers in data centers, as well as the server performance and lifetime. It requires more effective and efficient cooling solutions especially in the cases of cooling these high performance servers.

A server rack in a data center may contain servers and/or cooling distribution units having different types, sizes, gender, and location of liquid coolant connections. Typically, in a server rack, a coolant distribution unit couples to a coolant distribution manifold at the back of the server rack. Each server that requires liquid cooling will be connected to the coolant distribution manifold. The coolant distribution manifold often comprises a variety of interconnection hoses or a pair of distribution manifolds in the form of sealed square tubing with fluid connectors placed at fixed intervals along the tubing of the manifold. There are different types of rack manifold designs for server rack equipment connection sizes, locations, connector types, or genders. Servers and cooling distribution units in server racks require periodic service such that it is necessary to disconnect the liquid coolant connections at the back of the server rack to remove and service the server. Those connections are often deep in the back of the server rack and are not easily accessible. Blind mating of connectors requires a very high design and manufacturing accuracy which means a very low tolerance and deviations and errors to ensure proper blind mating.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention are illustrated by way of example and not limitation in the figures of the accompanying drawings in which like references indicate similar elements.

FIG. **1** is a block diagram illustrating an example of a cooling module in a server chassis having a system level structure for blind mating, according to one embodiment.

FIG. **2** illustrates plan view of an embodiment of a server chassis having a system level structure for blind mating, according to some embodiments.

FIGS. **3**A-**3**D illustrate a section view of a server chassis being blind mated to a coolant distribution manifold using system level structure for blind mating, according to some embodiments.

FIGS. **4**A and **4**B illustrate section views of a coolant distribution manifold having a guiding module for blind mating using a system level structure, according to some embodiments. FIG. **4**A is a side view and FIG. **4**B is a front view.

FIGS. **5**A and **5**B illustrate section views of a coolant distribution manifold in a server rack that supports blind mating using a system level structure, according to some embodiments.

FIGS. **6**A and **6**B illustrate section views of a server being blind mated to a coolant distribution manifold having a guiding module with an elastic element, according to some embodiments.

FIG. **7** illustrates a rear view of details of components of a server system level structure for blind mating, according to one embodiment.

FIGS. **8**A and **8**B illustrate rear views of a server rack that receives servers having a system level structure for blind mating, according to one embodiment.

DETAILED DESCRIPTION

Various embodiments and aspects of the inventions will be described with reference to details discussed below, and the accompanying drawings will illustrate the various embodiments. The following description and drawings are illustrative of the invention and are not to be construed as limiting the invention. Numerous specific details are described to provide a thorough understanding of various embodiments of the present invention. However, in certain instances, well-known or conventional details are not described in order to provide a concise discussion of embodiments of the present inventions.

Reference in the specification to “one embodiment” or “an embodiment” means that a particular feature, structure, or characteristic described in conjunction with the embodiment can be included in at least one embodiment of the invention. The appearances of the phrase “in one embodiment” in various places in the specification do not necessarily all refer to the same embodiment.

A blind mating connection structure for servers is disclosed. On the server side, a connector module has fluid connectors to be blind mated to fluid connectors on rack manifolds in a server rack. The connector module is coupled to a sliding channel on the server. The connector module slides horizontally and vertically in response to movement of a positioning slider on the connector module. On the rack manifold side, a guiding module has an opening that receives the positioning slider when the server is installed in the server rack. The guiding module tapers down to a centering point midway between each rack manifold. As the server is slid into the server rack, the positioning slider follows the guiding module to the center point, moving the connector module into alignment with the fluid connectors on the rack manifold for blind mating.

In a first aspect, a blind mating structure includes a connector module and a guiding module. The connector module is configured to be coupled to a sliding channel on a server. The sliding channel is configured to slide the connector module in a horizontal (x-axis) direction and/or a vertical (y-axis) direction. The connector module includes one or more fluid connectors coupled to the connector module. A first end of each fluid connector of the one or more fluid connectors is configured to be coupled to a coolant line within the server. A second end of each fluid connector is configured to be blind mated to one of one or more corresponding fluid connectors of one or more coolant distribution manifolds in a server rack when the server is installed into server rack. A positioning slider is coupled to the connector module. The positioning slider is configured to apply horizontal force, vertical force, or both horizontal and vertical force, to the connector module as the server is installed into the server rack. In an embodiment, a distance between a center of the positioning slider on the connector module to a location of each of the one or more fluid connectors on the connector module is adjustable. In an embodiment, an orientation of the one or more fluid connectors upon the connector module is selectable or adjustable.

The guiding module is configured to be coupled to the one or more coolant distribution manifolds. The guiding module has a tapered portion with an opening at a first end of the guiding module. The guiding module tapers from the first end to a centering point at a second end of the guiding module. The centering point is located in alignment with a center of the first end. The tapered portion is configured to receive the positioning slider from the connector module of the server being installed into the server rack. The tapered portion is further configured to guide the positioning slider toward the centering point at the second end of the guiding module as the server is inserted further into the server rack. Installing the server into the server rack cause alignment of the one or more fluid connectors on the connector module of the server with the one or more fluid connectors on the one or more coolant distribution manifolds. In an embodiment, the blind mating structure further includes the sliding channel. The sliding channel can slide using roller bearings or ball bearings. In an embodiment, the blind mating structure further includes a support frame that couples the sliding channel to the server. The positioning slider can include a ball head to facilitate smooth sliding action of the positioning slider along the guiding module. The one or more fluid connectors on the connector module can be quick-disconnect fluid connectors.

A length of the positioning slider can be determined by a length of the one or more fluid connectors coupled to the connector module, a length of the one or more corresponding fluid connectors on the coolant distribution manifold, a depth of engagement of the one or more fluid connectors coupled to the connector module with one or more corresponding fluid connectors on the coolant distribution manifold, and a depth of the guiding module coupled to the coolant distribution manifold. In an embodiment, the positioning slider can be replaced at the connector module, with a different length or different shape of positioning slider. The positioning slider can be designed in different shapes. In an embodiment, the positioning slider can be a rod-like shape. In an embodiment, a head portion of the positioning slider is shaped to be received by the tapered portion of the guiding module at the centering point of the guiding module. In an embodiment, the positioning slider can be substantially a same shape as the guiding module such that a base of the positioning slider is shaped substantially the same as the opening of the guiding module, and the positioning slider tapers from the base to a head that corresponds to the centering point at the furthest depth of the guiding module.

In some embodiments, the blind mating structure can further include an elastic connection fitted between the guiding module and the one or more coolant distribution manifolds. In response to the positioning slider of the server being in contact with the centering point of the guiding module, while the server is being inserted further into the server rack, the elastic connection can be compressed, moving the centering point further away from the first end of the guiding module. The elastic connection can be designed to be compressible in different ranges, depending upon requirements for specific server and/or server rack installations. In an embodiment, the guiding module can be made of stainless steel, epoxy coated steel, or high-impact plastic. The centering point can include a flexible detent that at least partially secures a ball head of the positioning slider to the centering point when the one or more fluid connectors on the one or more coolant distribution manifolds are blind mated to the one or more fluid connectors on the connector module.

In a second aspect, an electronic rack can include a plurality of coolant distribution manifolds, each comprising one or more fluid connectors. The electronic rack can include a server having a connector module as described in the first aspect. The server can also include a cooling module with a coolant supply line, a coolant return line, and a heat transfer unit. A first end of the coolant supply line and a first end of the coolant return line can be coupled to the heat transfer unit. The server can also include the guiding module as described above in the first aspect. The connector module and guiding module, together, align the plurality of fluid connectors on the connector module with a plurality of corresponding connectors on the coolant distribution manifolds, to blind mate the server coolant circulation system to the coolant distribution manifolds.

FIG. **1** is a block diagram illustrating an example of a cooling module in a server chassis having a system level structure for blind mating, according to one embodiment. The cooling module **100** can include a processor/cold plate assembly that removes heat from processor chip **101**. Referring to FIG. **1**, processor **101** is plugged onto a processor socket mounted on printed circuit board (PCB) or motherboard **102** coupled to other electrical components or circuits of a data processing system or server. Processor **101** includes a cold plate **103** attached to it, which is coupled to a rack manifold (not shown) via liquid supply line **132** and/or liquid return line **131** and the blind mating connection structure **300** described herein. A portion of the heat generated by processor **101** is removed by the cooling liquid lines **131** and **132** via cold plate **103**. The remaining portion of the heat enters into an air space underneath or above, which may be removed by an airflow generated by a cooling fan (not shown). A blind mating connection structure **300**, as described herein, can be coupled to the server chassis **105** using a frame (not shown). The blind mating structure **300**, including positioning slider **310**, is described in detail, below, with references to FIGS. **2**, **3**A-**3**D, **4**A-**4**B, **5**A-**5**B, **6**A-**6**B, **7**, and **8**. The cold plate cooling liquid lines **131** and **132** can be coupled to the blind mating connection structure **300** mounted to the frame on the server chassis **105** to enable blind mating of the server's cooling lines **131**/**132** to one or more coolant distribution manifolds (not shown) in the server rack (not shown) that houses the server chassis **105**. The liquid supply line **131** and liquid return line **132** can be hoses with either fluid **120** connectors or hose barb fittings. The cooling module **100** included in the server chassis **105** may be used in different types of servers and server racks. Blind mating connection structure **300** can ensure proper mating and configuration for the fluid systems between the server rack and the cooling module(s) in the server.

FIG. **2** illustrates a plan view of an embodiment of a server **203** having a blind mating connection structure, according to some embodiments. The blind mating connection structure enables a piece of information technology (IT) equipment, such as server **203**, to be slid into the server rack **200** and blind mated to a portion of the fluid connectors **212** on the coolant distribution manifolds **201** and **202** (collectively, **201/2**) via the blind mating connection structure. The blind mating connection structure can include two portions. A first portion includes a connector module **320** that is mounted to the chassis of server **203**. A second portion includes a guiding module **250** that is mounted between the coolant distribution manifolds **201** and **202**. The connectors **120** on the connector module **320** of the server blind mate to corresponding mating fluid connectors **212** on the coolant distribution manifolds **201** and **202** as the server is being slid into a server rack.

The fluid connectors **120** on the connector module **320** are initially configured to align, horizontally, diagonally, or vertically, with corresponding fluid connectors on the coolant distribution manifolds **201/2**. In an embodiment, connector module **320** can have pre-drilled holes, or "punch-outs" for commonly used orientations of fluid connectors such as 0° (horizontal), 45°, 180° (vertical), or 225°. In an embodiment, connector module **320** can include a rotatable plate with a slot that permits the fluid connectors **120** of the connector module **320** to be positioned at any angle within 0° to 360° and within a slidable spacing along the slot, such as 3" to 6" center-to-center between the fluid connectors **120**. Once an orientation (i.e. a rotation angle, if any, and distance between fluid connectors) is set for the fluid connectors **120** on the connector module **320**, the server can be repeatedly removed from the server rack and reinstalled by blind mating, without further adjustment. Connector module **320** is connected to a sliding channel **330** that enables connector module **320** to slide horizontally (x-axis) and/or vertically (y-axis) with respect to an insertion direction (z-axis) of the server **203** into the server rack **200**. An insertion direction is shown in FIG. **2** by the dashed arrow below the "server **203**" reference. A positioning slider **310**, coupled to the connector module **320**, extends from the connector module **320** in the same direction as the server is to slide into the server rack **200**. The head of the positioning slider **310** can have a ball end to facilitate to sliding along a guiding module **250** that is coupled to the coolant distribution manifolds **201** and **202** (collectively, **201/2**) in the server rack **200**. In embodiment, the positioning slider **310** can be replaced at the connector module **320** with a different positioning slider **310**, such as a positioning slider **310** that is longer, or wider, or has a different cross-sectional profile. A cross-sectional profile of the positioning slider can be circular, oval, triangular, square, hexagonal, or other cross-section shape.

As server **203** is slid into server rack (not shown), positioning slider **310** moves toward a first end of a tapered portion of guiding module **250**. The tapered portion is open at its widest in a direction facing toward server **203**, and the tapered portion slopes toward a centering point (not shown) at the deepest recess of guiding module **250**. If there is any misalignment between the positioning slider **310** and the centering point of guidance module **250**, the head of the positioning slider **310** comes into contact with the sloped sides of guiding module **250**. The sloped sides of guiding module **250** cause the positioning slider **310** to follow the slope of guiding module **250**, as server **203** is slid further toward the coolant distribution manifolds **201/2**. The sloped edges of guidance module **250** exert one or more forces onto the positioning slider **310**. The forces are transferred, by the positioning slider **310**, to the connector module **320**, causing the connector module **320** to slide along sliding channel **330**. The sliding action of the connector module **320** works to align the fluid connectors **120** on the connector module **320** with corresponding fluid connectors **212** on the coolant distribution manifolds **201/2**.

In FIG. **2**, a server **203** is illustrated that has a cooling module (not shown) included within the server **203**. The cooling module is described above with reference to FIG. **1**. The cooling module within the server **203** may include one or more hoses, tubes, or piping such as for a coolant supply line **131** and a coolant return line **132**, or other coolant line. The coolant lines **131/132** can be fluidly coupled at one end to the cooling module (not shown) in the server **203**. The other end of each of the coolant supply **131** and coolant return lines **132** can be coupled to a fluid connector **120** on the connector module **320**. In an embodiment, coolant lines **131** and **132** can also include fluid connectors **120** on their ends.

FIGS. **3**A through **3**D illustrate section views of a server **203** being blind mated to coolant distribution manifolds **201/202** using a blind mating connection structure, according to embodiments. The views in FIGS. **3**A through **3**D are from a side, or section, view of a server rack (not shown) that includes coolant distribution manifolds (or, "rack manifolds") **201/2** and a server **203** to be inserted into the server rack (not shown). In the views of FIGS. **3**A through **3**D, the coolant distribution manifolds **201/2** are located at a rear side (left, in FIGS. **3**A-**3**D) of the rack server (not shown) and the server **203** is being inserted into the rack server (not shown) from the front side (right, in FIGS. **3**A-**3**D) of the rack server (not shown) toward the coolant distribution manifolds **201/2**. Guiding module **250** is shown coupled to rack manifolds **201/2**, with centering point **251** at the deepest portion of guiding module **250**. Guiding module **250** is mounted to, and between, coolant distribution manifold **201** and coolant distribution manifold **202**. Centering point **251** is equidistant between a centerline of a fluid connector **212** on coolant distribution manifold **201** (e.g. a coolant supply distribution manifold) and a centerline of a fluid connector **212** on coolant distribution manifold **202** (e.g. a coolant return distribution manifold). Server **203** is installed from right to left, as indicated by the dashed arrow labeled "install server."

FIG. **3**A illustrates key components of the blind mating structure. FIG. **3**A illustrates a status of the blind mating structure before the server is populated into a server rack (not shown). Key components of the server side of the blind mating structure include a positioning slider **310**, a connector module **320**, and a sliding channel **330**. In an embodiment, positioning slider **310** may include a ball at the head of the positioning slider **310** which facilitates movement of the positioning slider **310** over the surface of a guiding module **250** on the rack manifold side of the blind mating structure. Connector module **320** includes one or more fluid connectors **120**. Each fluid connector **120** corresponds to a coolant line inside of server **203**. One end of the coolant line is coupled a cooling module inside the server **203**. The other end of the coolant line is coupled to the fluid connector **120**. Connector module **320** is coupled to a sliding channel **330** that enables the connector module **320** to slide in the horizontal and vertical direction, in the plane of the rear of the server **203**. Connector module **320** slides along sliding channel **330** in response to forces applied to positioning slider **310** exerted by positioning slider **310** contacting an inner surface of guiding module **250**, as the server **203** is being installed into the server rack (not shown).

On the rack manifold side, a guiding module **250** is installed between two rack manifolds **201/202** (collectively, **201/2**), each rack manifold having one or more fluid connectors **212** associated with the rack manifold. The rack manifolds **201/2** can be a coolant supply distribution manifold and a coolant return manifold for circulating cooling liquid through a cooling module of the server **203**. The guiding module **250** can include a guiding surface which can include guiding channels formed into the surface of the guiding module **250**. For example, a guiding module **250** can have a rectangular opening at a first end of the guiding module **250**. The opening on the first end of the guiding module **250** faces toward the server **203** as the server **203** is being installed in the server rack (not shown). The opening on the first end of the guiding module **250** tapers to a centering point **251** at a second end of the guiding module **250**. The centering point **251** is a deepest point (i.e., furthest away from the server **203**) within the guiding module **250**. The centering point **251** is located on the guiding module **251** between the two rack manifolds **201/2**, at a point that is equidistant from each of the two rack manifolds **201/2**.

FIG. **3**B illustrates the operation of the blind mating structure during populating of the server **203** into the server rack (not shown). Referring now to FIG. **3**B, it can be seen that the server **203** fluid connectors **120** are not aligned with the rack fluid connectors **212**. As the server **203** is installed into the rack, the positioning slider **310** first contacts the guiding channel within the guiding module **250**. The positioning slider **310** contacts the sloped surface of the guiding module **250** and the positioning slider **310** slides along the surface of the guiding module **250**, toward centering point **251**. The sloped surface in guiding module **250**, in combination with the force of sliding the server **203** into the server rack (not shown), generates vector force components upon positioning slider **310** in one or more of the horizontal (x-axis) and vertical (y-axis) directions, with respect to the rear face of the server **203**. As indicated by the label "slider moving" and the corresponding dashed arrow facing diagonally down and left, the positioning slider **310** moves along the sloped surface of the guiding module **250** as server **203** is installed into the server rack (not shown). The forces upon the positioning slider **310** are transferred by the positioning slider **310** to connector module **320**, causing connector module **320** to slide along sliding channel **330**, indicated by the label "connector module moving" and the dashed arrow directed downward.

Referring now to FIG. **3**C, an intermediate position is illustrated, during the populating of the server **203** in the server rack (not shown). The positioning slider **310** may directly match to the, e.g., vertical centerline of the guiding module **250** in one scenario. The positioning slider **310** may continue to move towards the guiding module **250** and then move along the face of the guiding channel **250**. It is rare for the connector module **320**, and thus positioning slider **310**, to be initially in this configuration wherein the positioning slider **310** is nearly centered to the centering point **251** before populating of the server **203** into the server rack (not shown) is complete. However, this may be a common occurrence after a first time that the server **203** has been populated to the server rack (not shown). After an initial installation of the server **203** into the server rack, positioning slider **310**, and thus the connector module **320**, may remain reasonably close to a position of alignment with the centering point **251** for subsequent installations of the server **203** into the server rack.

Movement of connector module **320** aligns the fluid connectors **120** with the corresponding mating fluid connectors **212** on the coolant distribution manifolds **201/202**. The positioning slider **310** is coupled to connector module **320**. Connector module **320** is coupled to a sliding channel **330**. Sliding channel **330** slides horizontally and/or vertically, in response to a location of the head of the positioning slider **310**, as the server **203** being installed into the server rack (not shown). When the ball head of the positioning slider **310** reaches the centering point **251**, the connector module **320** is aligned with centering point **251**. Fluid connectors **120** of connector module **320** are now aligned with connectors **212** of the rack manifolds, ready to perform blind mating of the fluid connectors **120** and fluid connectors **212**.

Referring now to FIG. **3**D, server **203** is shown fully slid into position in the server rack (not shown). Fluid connectors **120** on connector module **320** are fully aligned and blind mated to fluid connectors **212** on coolant distribution manifolds **201/2**. Positioning slider **310** is seated into centering point **251** of guiding module **250** in a "locked position." In an embodiment, centering point **251** may include a detent that at least partially secures the ball head of the positioning slider **310** into the centering point **251**. Further locking forces are generated by the act of mating fluid connectors **120** to fluid connectors **212**. Once the positioning slider reaches the centering point **251**, the fluid connectors **120** and **212** may perfectly blind mate. However, this may not always happen due to many factors. The blind mating structure disclosed herein addresses scenarios to provide complete and accurate blind mating.

FIGS. **4**A and **4**B illustrate section views of a coolant distribution manifold having a guiding module for blind mating using a system level structure, according to some embodiments. FIG. **4**A illustrates a side view of guiding module **250** mounted to coolant distribution manifolds ("rack manifolds") **201/2**. FIG. **4**B illustrates an end view, looking from a server **203** in the server rack (not shown) toward rack manifolds **201/2** mounted in the rear of the server rack (not shown).

Elastic section **253** can be mounted between guiding module **250** and rack manifolds **201/2**. As is known in the art, server racks are often provided with a mechanical "stop" tab or ear on a frame of the server rack that prevent the server from being inserted into the frame beyond the "stop" point. The stop point is a maximum distance that a server may be installed into the server rack (not shown), with respect to a front of the server rack. However, a distance of a front face of the rack manifolds, facing into the server rack, may not be sufficiently exact for full mating of the fluid connectors **120** on the server **203** to fluid connectors **212** on the rack manifolds **201/2**. In the embodiment of FIGS. **4**A and **4**B, an elastic connection **253** can absorb a small amount of a difference in distance between the fluid connectors **120** on the connector module **320** to ensure full and proper mating to the fluid connectors **212** on the rack manifolds **201/202**. As the server **203** is pushed into the server rack (not shown), if the positioning slider **310** contacts the centering point **251** of the guiding module **250** before the server **203** reaches the "stop" tab in the server rack, and before the fluid connectors **120** and **212** are fully blind mated, the positioning slider **310** pushes on the centering point **251** of the guiding module **250** and compresses the elastic connection **253** a small amount until the fluid connectors **120** and **212** are fully blind mated. The entire guiding module **250**, including centering point **251**, can be pushed to the left side in FIG. **4**A causing a compression of the elastic connection **253**. The compression rate of the elastic connection **253** can vary to accommodate different scenarios.

FIGS. **5**A and **5**B illustrate section views of coolant distribution manifolds ("rack manifolds") **201/202** in a server rack (not shown) that supports a blind mating connection structure, according to some embodiments. The blind mating connection structure described in FIGS. **4**A and **4**B, above, is extended to illustrate four guiding modules **250**, each with an elastic connection **253** fixed between the guiding module **250** and the rack manifolds **201/202**. In an embodiment, elastic connection **253** can be a strip of low density, compressible, foam rubber, or a low density compressible rubber. In an embodiment, the elastic connection **253** can be in the form of a strip of material on the face of the rack manifolds. In an embodiment, a single strip of material can be applied, such as with an adhesive or self-adhesive, to accommodate a plurality of guiding modules **250**. Each guiding module **250** is configured to receive a positioning slider (not shown) of a connector module (not shown) to facilitate blind mating of a plurality of fluid connectors (not shown) on a connector module (not shown) attached to a server (not shown) to a pair of fluid connectors **212** on a pair of rack manifolds **201**/**202**. Blind mating operation and functionality of guiding module **250**, centering point **251**, elastic connection **253**, rack manifolds **201**/**202** and fluid connectors **212** have been described above and will not be repeated again here.

The guiding module can be attached to an existing rack manifold to add the guiding feature to an existing server rack. Although in FIGS. **5**A and **5**B the guiding modules **250** have been illustrated as being similar, or the same, this needed not be the case. Different configurations of guiding modules **250** can be implemented for differing server types installed, or to be installed, into the server rack and for different configurations of server racks.

FIGS. **6**A and **6**B illustrate section views of a server **203** being blind mated to fluid connectors **212** of coolant distribution ("rack") manifolds **201**/**202** having a guiding module **250** with an elastic connection **253**, according to some embodiments. Referring to FIG. **6**A, as the server **203** is installed into the server rack (not shown), positioning slider **310** may reach the centering point **251** of guiding module **250** before the fluid connectors **120** on the connector module **320** of the server **203** fully connects ("blind mates") to corresponding fluid connectors **212** on rack manifolds **201**/**202**. In FIG. **6**A, this is shown by label "fluid disconnection," pointing to the gap between fluid connectors **212** and fluid connectors **120**.

Referring now to FIG. **6**B, to fully blind mate the fluid connectors **120** and **212**, additional movement can be provided to further push the server **203** into the server rack (not shown). The additional movement is indicated by the dashed line arrow, pointing left in the FIG. **6**B. The additional movement is further indicated by compression of the elastic connection **253**, labeled "additional movement" in FIG. **6**B. The additional movement causes the positioning slider **310** to push on the guiding module **250**, thereby compressing the elastic connection **253** by a small amount. The fluid connectors **120** and **212** are now fully blind mated, making a completed fluid connection. In an embodiment, the centering point **251** can have a small detent that captures, or partially captures, a ball end on the head of the positioning slider **310** to help retain the fluid connector mating.

FIG. **7** illustrates an end view of components of a system level structure for blind mating, according to one embodiment. FIG. **7** shows the portion of the blind mating connection structure that attaches to the rear of the server **203**. The server side of the blind mating structure includes one or more fluid connectors **120** coupled to connector module **320**. Inside the server, one end of a coolant supply line and one end of a coolant return line (not shown) are coupled to a heat transfer unit (not shown) of a cooling module (not shown). The other end of the coolant supply line (not shown) is coupled to one of the fluid connectors **120**, and the other end of the coolant return line (not shown) is coupled to the other of the fluid connectors **120**, on the connector module **320**. The connector module **320** is coupled to sliding channel **330**. The connector module **320** can slide along sliding channel **330** in the vertical direction (y-axis), as indicated by the two vertical arrows at the connector module **320**. The sliding frame **330** also enables the connector module **320** to slide horizontally (x-axis) as indicated by the two horizontally opposing arrows. In an embodiment, sliding frame **330** can be fixed to the server **203** using a support frame **302**. In an embodiment, sliding frame **330** can be constructed such that sliding frame **330** can be attached to a chassis of the server without using a support frame **302**.

Sliding frame **330** can be constructed from formed channel material having roller bearings, ball bearings, lubricant, and/or other materials to facilitate the sliding action the sliding frame **330**. Formed channel material can be metal, e.g. steel, stainless steel, aluminum or other material. Channels material can be cut from known shapes, e.g. c-shaped channel or box channel or can be cut or machined from other known shapes. In an embodiment, channel material can be formed by extrusions or press-shaping to configurations such as are used in furniture drawers, racks, or other sliding rails.

Positioning slider **310** is an elongated member, fixed to the connector module **320** to be perpendicular to a plane of the rear of the server **203**. In an embodiment, positioning slider **310** is removable and replaceable from the connector module **320**, such as to accommodate installation of an appropriate length and/or type of positioning slider **310** for a particular installation. A cross-section of the positioning slider **310** can be round, oval, square, oblong, or other shape. A length of the positioning sliding **310** can be based upon a distance between a "stop" tab in the server rack (or a suitably designed fixed rear-end point for the server when installed in the rack). The length of the positioning slider **310** is further determined based upon a depth of the connector module **320** from the rear of the server **203**, a distance from the face of the connector module to an end of the fluid connectors **120** that are coupled to connector module **320**, a length of the fluid connectors **212** on rack manifolds **201**/**2**, and a depth of guiding module **250** from a face of the rack manifolds **201**/**2** to a deepest point of the guiding module **250** at the centering point **251**. Cross-sectional shape and dimensions of the cross-sectional shape of the positioning slider **310** can be chosen based upon the determined length of the positioning slider **310**. Cross-sectional of the positioning slider **310** can further be based upon a steepness of the sloped sides of the guiding module, the horizontal and vertical forces applied to the positioning slider **310** during installation of the server **203** into the server rack, and resistance forces in the sliding channel **330** movement. Design of the cross-sectional shape and dimensions of the positioning slider **310** ensure that the positioning slider **310** remains straight, rigid, and does not bend substantially during use in sliding the position the connector module **320**.

FIGS. **8**A and **8**B illustrate rear views of a server rack **200** that receives servers **203** having a system level structure for blind mating, according to one embodiment. In FIGS. **8**A and **8**B, the view is from the perspective of the front of the server rack **200**, looking through the server rack **200**, toward the rear of the server rack **200**. Components of both the server **203** side of the blind mating connecting structure and the rack manifolds **201**/**2** side of the blind mating connecting structure are shown.

Referring to FIG. **8**A, server rack **200** has two servers **203** installed in the server rack **200**. Two rack manifolds **201**/**202** are installed in the rear of the server rack **200**. Rack manifolds **201**/**2** can be, e.g., a coolant supply distribution manifold and a coolant return collection manifold. The rack manifolds **201**/**2** can each be configured as a sealed elongated tubing, e.g. square tubing, having a plurality of fluid connectors **212** connected at predetermined intervals. Typically, a pair of fluid connectors **120** on a connector module **320** on server **203** will be blind mated to a corresponding pair of rack manifolds. In the configuration of FIG. **8**A, the two rack manifolds **201/2** are sufficiently close together that a single connector module **320** having fluid connectors **120** on each server **203** can blind mate to corresponding fluid connectors **212** on rack manifolds **201/2**. Each connector module **320** is coupled to sliding channel **330** that is, in turn, connected to a chassis of the server **203**. The connector module **320** further includes a positioning slider **310**. Details and operation of the connector module **320** and its components are described above with reference to at least FIGS. **2**, **3**A-**3**D, **4**A-**4**B, **6**A-**6**B and **7** and will not be described again here.

Each pair of fluid connectors **212** that blind mate to one server has a guiding module **250** installed between the pair of fluid connectors **212** on rack manifolds **201/2**. Each guiding module **250** has a centering point **251**, and can optionally have an elastic connection **253** installed between the guiding module **250** and the rack manifolds **201/2**. The guiding modules **250**, centering point **251**, and elastic connection **253** have been described in detail, above, with reference to FIGS. **2**, **3**A-**3**D, **4**A-**4**B, **5**A-**5**B, **6**A-**6**B and **7** and will not be described again here.

Referring now to FIG. **8**B, two servers **203** are installed in rack server **200**. Here, rack manifold **201** and rack manifold **212** are separated, one for coolant supply and one for coolant return. One rack manifold is installed at the far left of the server rack **200** and the second rack manifold is installed at the far right of the server rack **200**. In this embodiment, two connector modules **320** can be used, with each connector module **320** having a single fluid connector **120** and a positioning slider **310**. The single fluid connector **120** can correspond to one of the either the coolant supply line or coolant return line (not shown) inside the server **203**. Each connector module **320** is fixed to its own sliding channel **330** that enables the connector module **320** to slide in the horizontal (x-axis) direction and the vertical (y-axis) direction in response to positioning slider **310** contacting the inner faces of guiding module **250**. Similarly, at the right in FIG. **8**B, a single fluid connector **120** is coupled to another connector module **320** for the server **203**. The single fluid connector **120** corresponds to, e.g., the other of the coolant supply line or coolant return line (not shown) inside the server **203**. In other respects, operation of the connector module **320** with the single fluid connector **120** are similar the connector module with a single fluid connector **120** that has already been described in FIG. **8**B. In FIG. **8**B, a manner of attachment of the guiding module **250** to the rack manifold **201** or **202** can have additional rigidity in its design to ensure that guiding module **250** does not flex substantially at its connection point to rack manifold **201** or **202**. In other respects, the design and functionality of guiding module **250** and connector module **320** are substantially the same as previously described embodiments. In FIG. **8**B, elastic connection **253** can be coupled between guiding module **250** and a rack manifold **201** or **202**.

In the foregoing specification, embodiments of the invention have been described with reference to specific exemplary embodiments thereof. Different selection of connector types, hose, tubing, piping, and structural frame members, and orientations of assemblies can be implemented by one of skill in the art in possession of this disclosure. Different server rack orientations, e.g. vertical, or upward/downward, can be implemented using this disclosure. It will be evident that various modifications may be made thereto without departing from the broader spirit and scope of the invention as set forth in the following claims. The specification and drawings are, accordingly, to be regarded in an illustrative sense rather than a restrictive sense.

What is claimed is:

1. A blind mating structure comprising:

a connector module configured to be coupled to a sliding channel on a server, the sliding channel configured to slide the connector module in a horizontal (x-axis) direction and a vertical (y-axis) direction, the connector module having:

one or more fluid connectors coupled to the connector module, a first end of each fluid connector of the one or more fluid connectors configured to be fluidly coupled to a coolant line within the server, and a second end of each fluid connector configured to be blind mated to one of one or more corresponding fluid connectors of one or more coolant distribution manifolds in a server rack when the server is installed into the server rack, and

a positioning slider coupled to the connector module, the positioning slider configured to apply horizontal force, vertical force, or both horizontal and vertical force, to the connector module as the server is installed into the server rack; and

a guiding module, configured to be coupled to the one or more coolant distribution manifolds, the guiding module having a tapered portion with an opening at a first end of the guiding module, and the guiding module tapering from the first end to a centering point at a second end of the guiding module,

wherein the positioning slider applies the horizontal force, the vertical force, or both the horizontal and the vertical force to the connector module in response to the positioning slider contacting the tapered portion of the guiding module during installation of the server into the server rack.

2. The blind mating structure of claim **1**, wherein the centering point is located in alignment with a center of the first end, wherein the tapered portion is configured to receive the positioning slider from the connector module of the server being inserted into the server rack, and wherein the tapered portion is configured to guide the positioning slider toward the centering point at the second end of the guiding module as the server is inserted further into the server rack, thereby aligning the one or more fluid connectors on the connector module of the server with the one or more fluid connectors on the one or more coolant distribution manifolds.

3. The blind mating structure of claim **1**, further comprising a support frame that couples the sliding channel to the server.

4. The blind mating structure of claim **1**, wherein the positioning slider comprises a ball head.

5. The blind mating structure of claim **1**, wherein a head portion of the positioning slider is shaped to be received by the tapered portion of the guiding module at the centering point of the guiding module.

6. The blind mating structure of claim **1**, wherein the sliding channel comprises roller bearings or ball bearings.

7. The blind mating structure of claim **1**, wherein a length of the positioning slider is determined by a length of the one or more fluid connectors coupled to the connector module, a length of the one or more corresponding fluid connectors on the coolant distribution manifold, a depth of engagement of the one or more fluid connectors coupled to the connector module with one or more corresponding fluid connectors on the coolant distribution manifold, and a depth of the guiding module coupled to the coolant distribution manifold.

8. The blind mating structure of claim **1**, wherein the positioning slider is replaceable at the connector module, with a different length or different shape of positioning slider.

9. The blind mating structure of claim **1**, further comprising an elastic connection fitted between the guiding module and the one or more coolant distribution manifolds, such that, in response to the positioning slider of the server being in contact with the centering point while the server is being inserted further into the server rack, the elastic connection is compressed, moving the centering point further away from the first end of the guiding module.

10. The blind mating structure of claim **1**, wherein an orientation of the one or more fluid connectors upon the connector module is selectable or adjustable.

11. The blind mating structure of claim **10**, wherein a distance between a center of the positioning slider on the connector module to a location of each of the one or more fluid connectors on the connector module is adjustable.

12. The blind mating structure of claim **1**, wherein the centering point comprises a flexible detent that at least partially secures a ball head of the positioning slider to the centering point when the one or more fluid connectors on the one or more coolant distribution manifolds and corresponding fluid connectors on the connector module are blind mated.

13. An electronic rack, comprising:

a plurality of coolant distribution manifolds, each comprising one or more fluid connectors;

a server, the server including:

a cooling module having a coolant supply line, a coolant return line, and a heat transfer unit, wherein a first end of the coolant supply line and a first end of the coolant return line are coupled to the heat transfer unit;

a connector module coupled to a sliding channel that is coupled to the server, the sliding channel configured to slide the connector module in a horizontal (x-axis) direction and a vertical (y-axis) direction, the connector module having:

a plurality of fluid connectors coupled to the connector module, wherein each fluid connector of the plurality of fluid connectors is coupled to either a second end of the coolant supply line or a second end of the coolant return line, and each fluid connector is configured to blind mate to one of a plurality of corresponding fluid connectors on a coolant distribution manifold of the plurality of coolant distribution manifolds in the electronic rack, and

a positioning slider coupled to the connector module, the positioning slider configured to apply a horizontal force (x-axis), a vertical force (y-axis), or both a horizontal and a vertical force to the connector module; and

a guiding module, coupled to the plurality of coolant distribution manifolds, the guiding module having a tapered portion with an opening at a first end of the guiding module and the guiding module tapering from the first end to a centering point at a second end of the guiding module,

wherein the positioning slider applies the horizontal force, the vertical force, or both the horizontal and the vertical force to the connector module in response to the positioning slider contacting the tapered portion of the guiding module during installation of the server into the electronic rack.

14. The electronic rack of claim **13**, further comprising an elastic connection fitted between the guiding module and the plurality of coolant distribution manifolds such that, in response to the positioning slider of the server being in contact with the centering point while the server is being inserted further into the electronic rack, the elastic connection is compressed, moving the centering point further away from the first end of the guiding module.

15. The electronic rack of claim **13**, wherein the centering point is located in alignment with a center of the first end, wherein the tapered portion is configured to receive the positioning slider from the connector module of the server being inserted into the electronic rack, and wherein the tapered portion is configured to guide the positioning slider toward the centering point at the second end of the guiding module as the server is inserted further into the electronic rack, thereby sliding the connector module and aligning the plurality of fluid connectors on the connector module of the server with the plurality of corresponding fluid connectors on the plurality of coolant distribution manifolds.

16. The electronic rack of claim **13**, wherein a length of the positioning slider is determined by a length of the plurality of fluid connectors coupled to the connector module, a length of the plurality of corresponding fluid connectors on the coolant distribution manifold, and a depth of the guiding module coupled to the plurality of coolant distribution manifolds.

17. The electronic rack of claim **16**, wherein a width or diameter of the positioning slider is determined by the length of the positioning slider and a magnitude of the horizontal force and a magnitude of the vertical force imposed upon the positioning slider as the server is inserted into the electronic rack.

18. The electronic rack of claim **13**, wherein the positioning slider is replaceable at the connector module with a different length or different shape of positioning slider.

19. The electronic rack of claim **13**, wherein a head portion of the positioning slider is shaped to be received by the tapered portion of the guiding module at the centering point of the guiding module, and wherein an orientation and location of the one or more fluid connectors on the connector module is selectable or adjustable.

20. The electronic rack of claim **13**, wherein the centering point comprises a flexible detent that partially secures a ball head of the positioning slider to the centering point when the one or more fluid connectors on the plurality of coolant distribution manifolds and corresponding fluid connectors on the connector module are blind mated.

* * * * *